

Using a Detailed 3-D Cloud-Resolving Model to Simulate Cloud Particle Size Distributions

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Introduction

- Overview

- predictive power relies on depth of understanding
- clouds and weather are chaotic but deterministic
- numerical simulation is the tool of choice
- simulation method (model) depends upon the problem at hand
- complexity chosen in focus area (microphysics + dynamics)

- Problems

- climate (not weather, precipitation)
 - aerosol effects on clouds
 - cirrus cloud properties
- general cloud physics (climate, seeding, aviation)
 - how does “warm rain” form?
 - how does “cold rain” (ice) form?

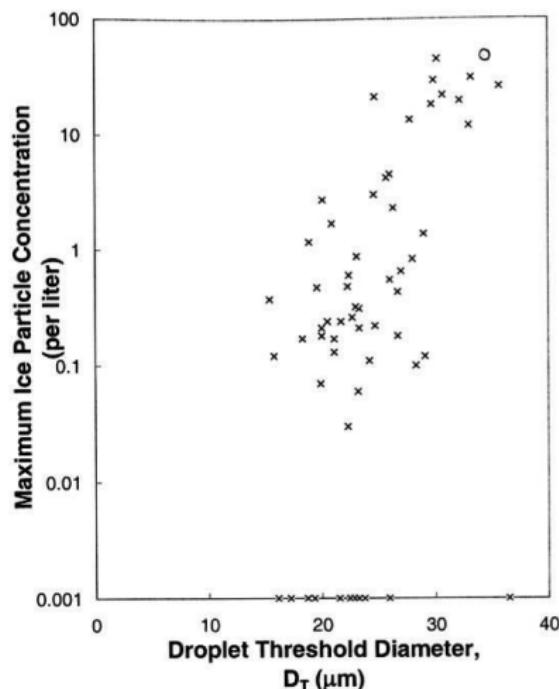
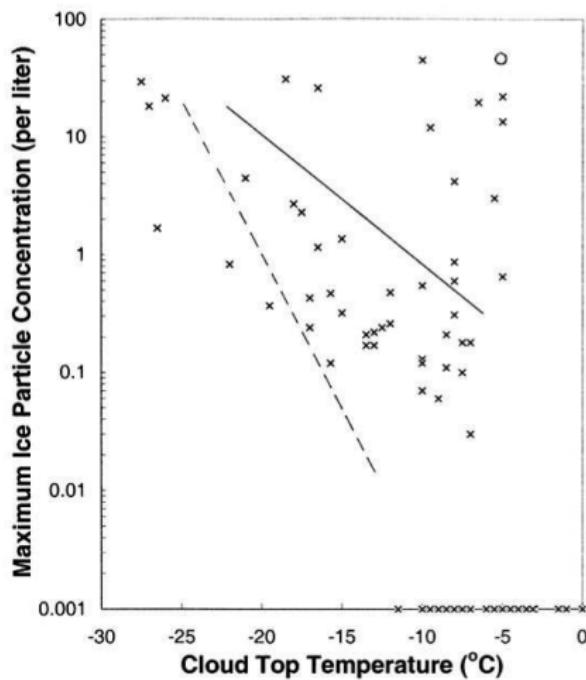
Microphysical Processes

- drop formation (condensation, evaporation)
 - gravitational collection (collision, coalescence)
 - sedimentation
 - homogeneous ice formation ($T < -38^\circ C$)
 - heterogeneous ice formation ($T > -38^\circ C$)

Mechanism	Temp, C	Supersat	Dependence	Description
Primary modes	$-4 > T > -14$	—	$f_{lin}(T)$	$\text{IN}_{aer} + \text{drop} \rightarrow \text{ice}$
	$-8 > T > -22$	$0 < S_w$	$f_{lin}(T)$	$\text{IN}_{aer} + \text{vapor} \rightarrow \text{ice}$
	$-10 > T$	$0 < S_i < 0.2$	$f_{exp}(S)$	$\text{IN}_{aer} + \text{vapor} \rightarrow \text{ice}$
	$-10 > T > -24$	—	$f_{lin}(T)$	$\text{drop} + \text{IN}_{drop} \rightarrow \text{ice}$



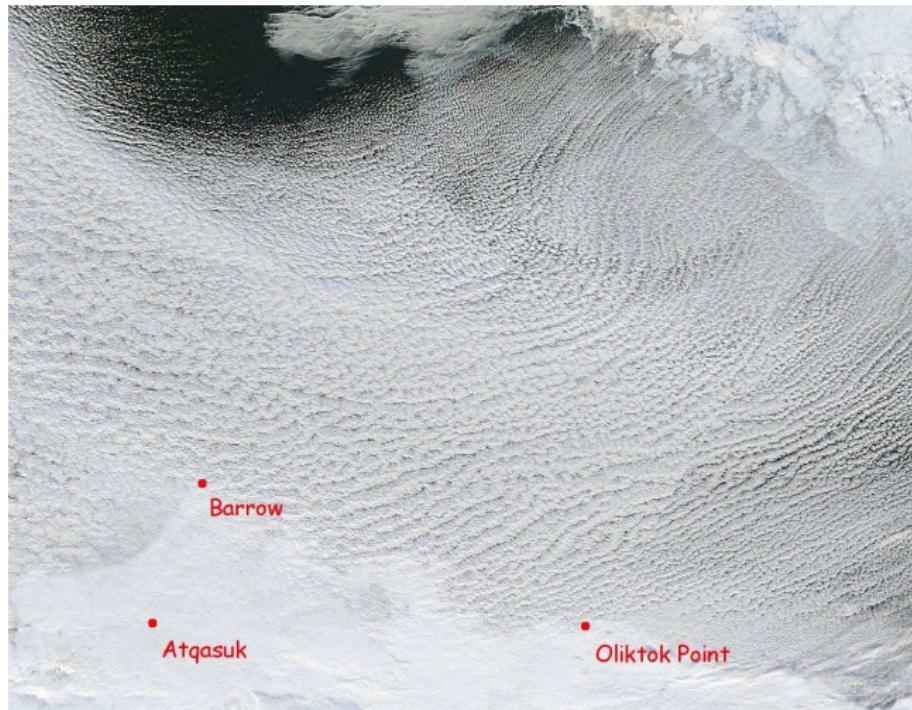
Mixed-Phase Arctic Clouds During the 1998 FIRE-ACE/SHEBA Experiment

Ice Number \propto Temperature?

Source: Rangno and Hobbs, JGR 106:15,065, 2001

2004 Mixed-Phase Arctic Cloud Experiment (M-PACE)

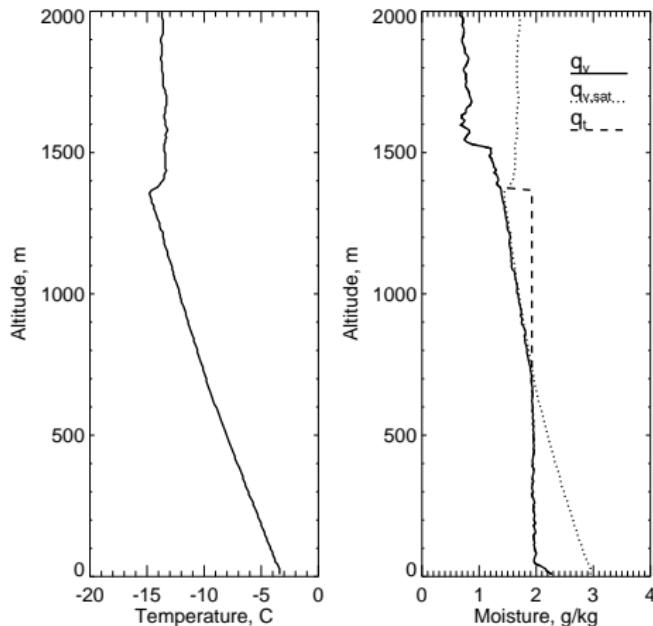
Barrow, Alaska



Source: AVHRR, image courtesy of Hans Verlinde and Jerry Harrington, Pennsylvania State University

2004 Mixed-Phase Arctic Cloud Experiment (M-PACE)

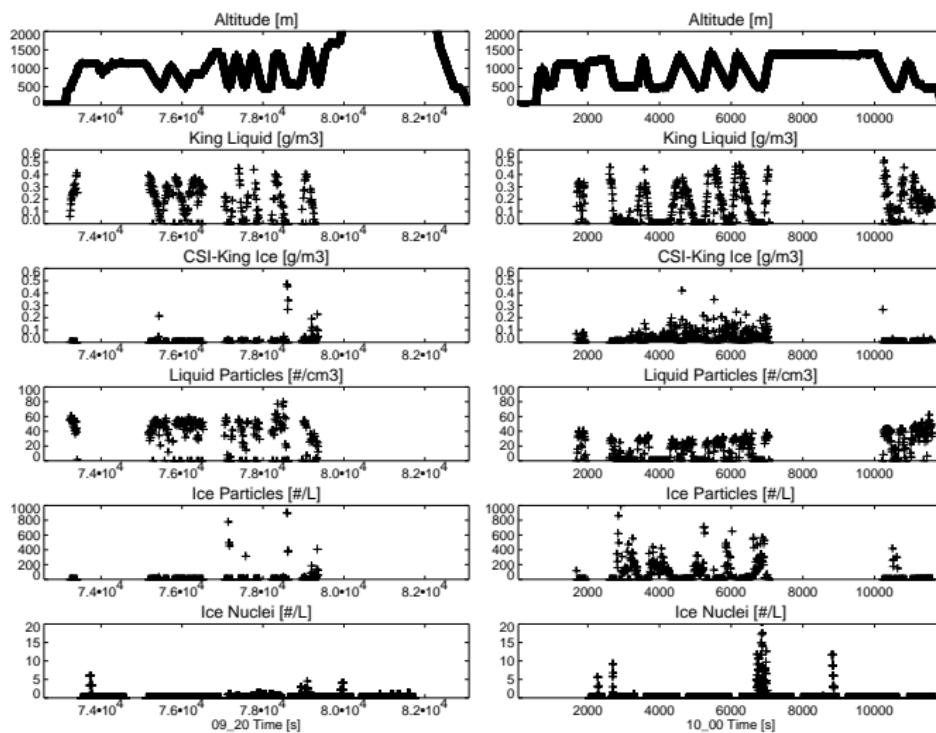
Environmental Conditions



Source: AVHRR, image courtesy of Hans Verlinde and Jerry Harrington, Pennsylvania State University

2004 Mixed-Phase Arctic Cloud Experiment (M-PACE)

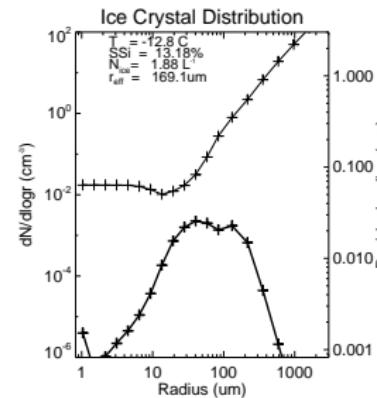
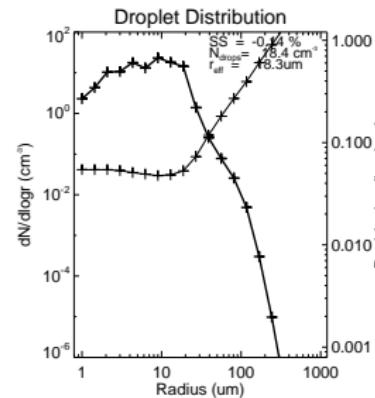
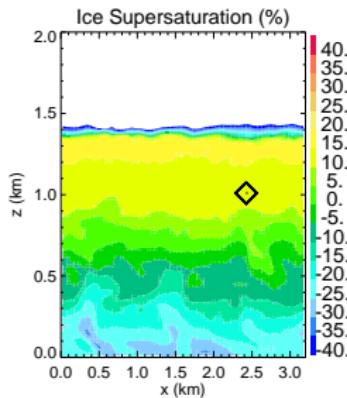
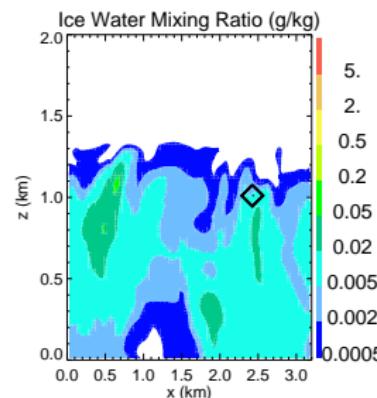
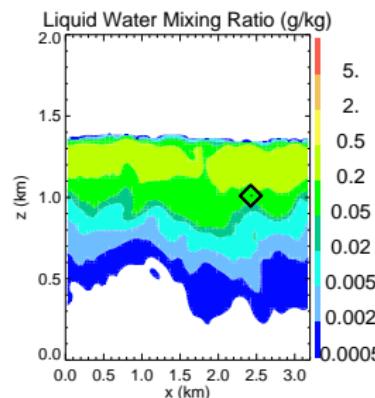
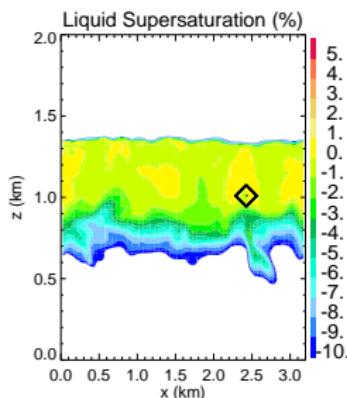
Flight Data



Source: AVHRR, Hans Verlinde and Jerry Harrington / Penn State

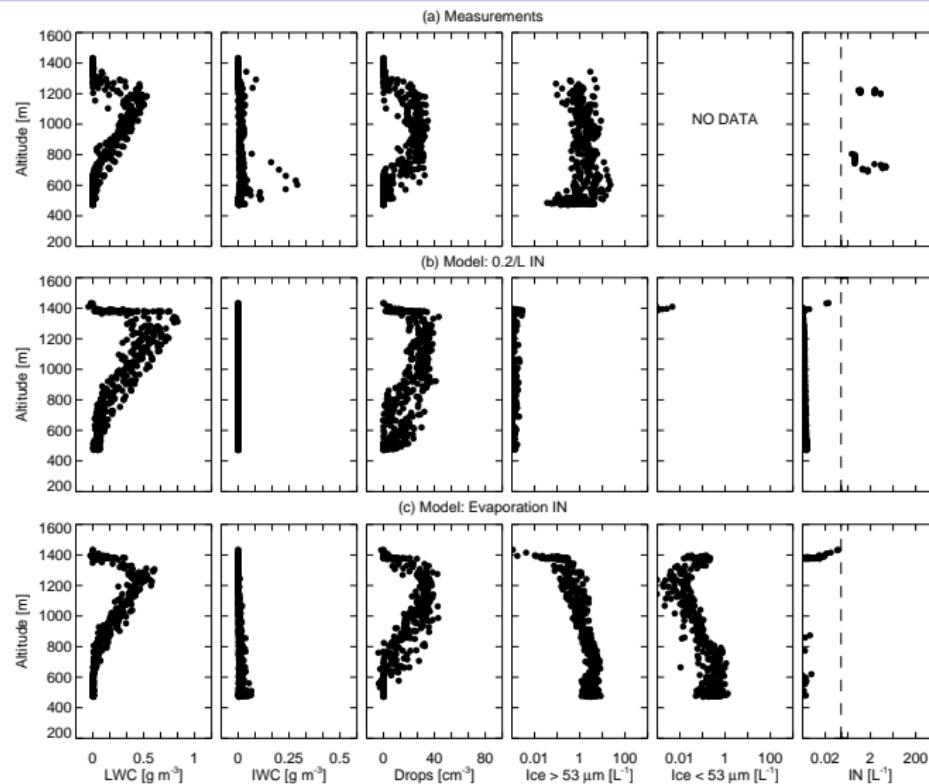
2004 Mixed-Phase Arctic Cloud Experiment (M-PACE)

Model Results



2004 Mixed-Phase Arctic Cloud Experiment (M-PACE)

Flight Data vs Model Results



Source: Fridlind et al., JGR, 2007

Hypothesized Ice Formation Mechanisms

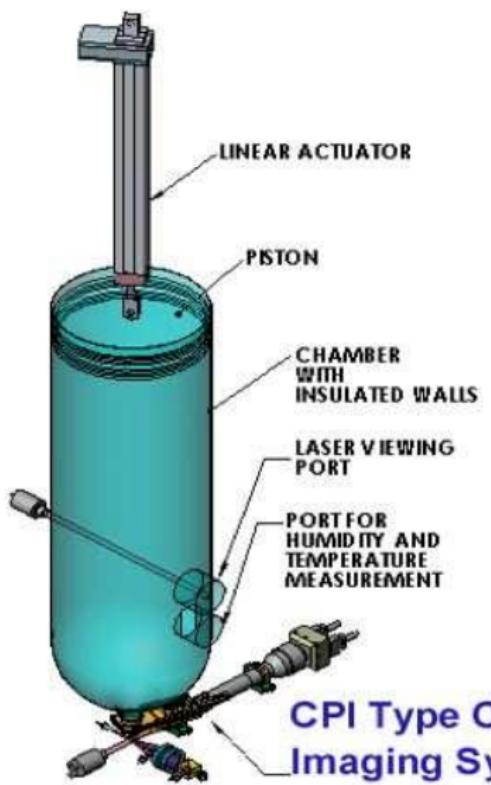
- evaporation nuclei [Beard, 1992]
 - according to Langer et al. [1979], first suggested by Georgii [1959]
 - one in $10^4\text{--}10^5$ drop residuals [Rosinski and Morgan, 1991]



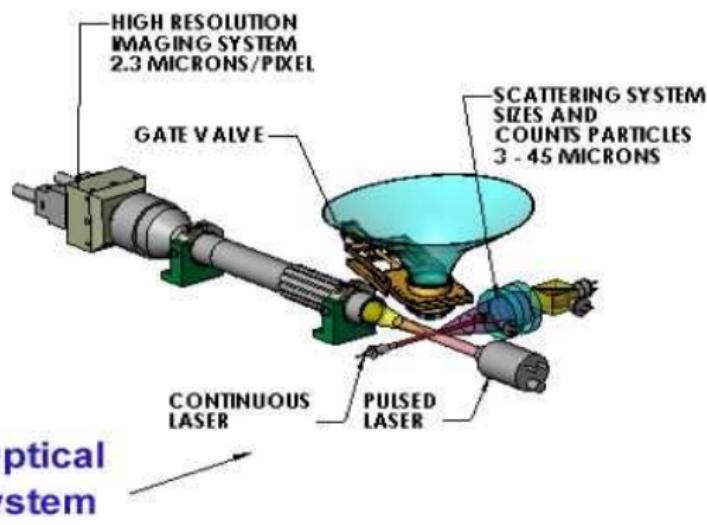
- evaporation freezing
 - ice nucleation during drop evaporation [Cotton and Field, 2002]
 - as via organic films [Cantrell and Robinson, 2006]



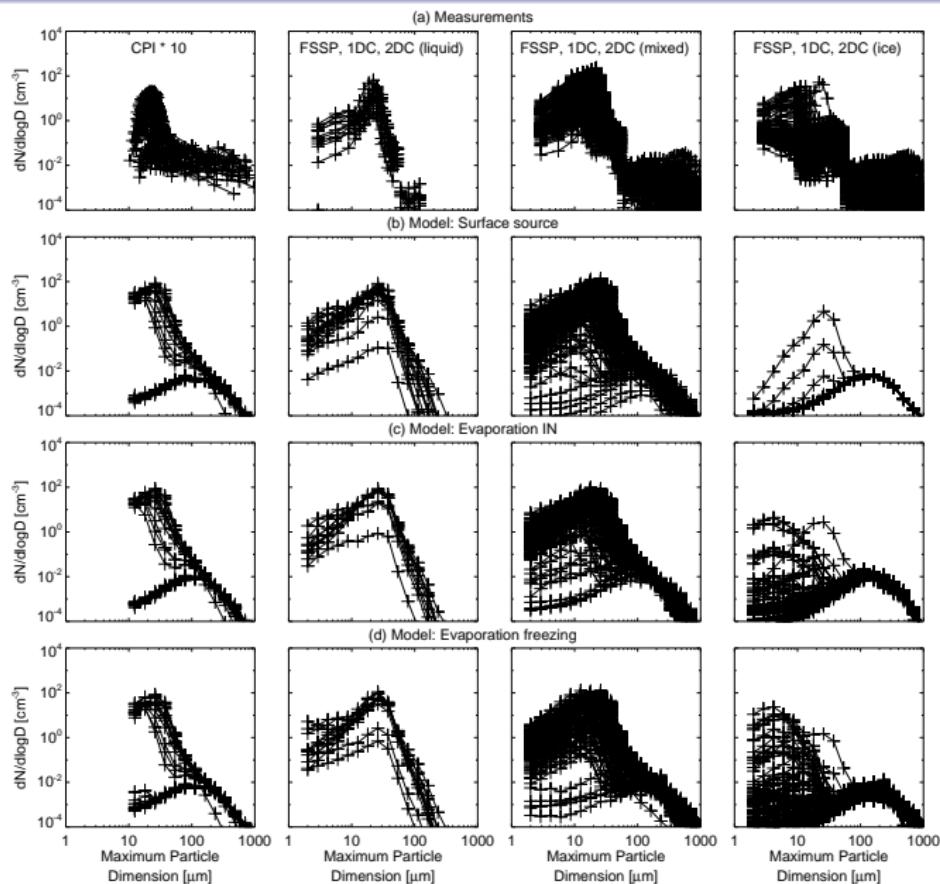
Proposed Instrument Design (SPEC, Inc.)



Evaporation Freezing Chamber

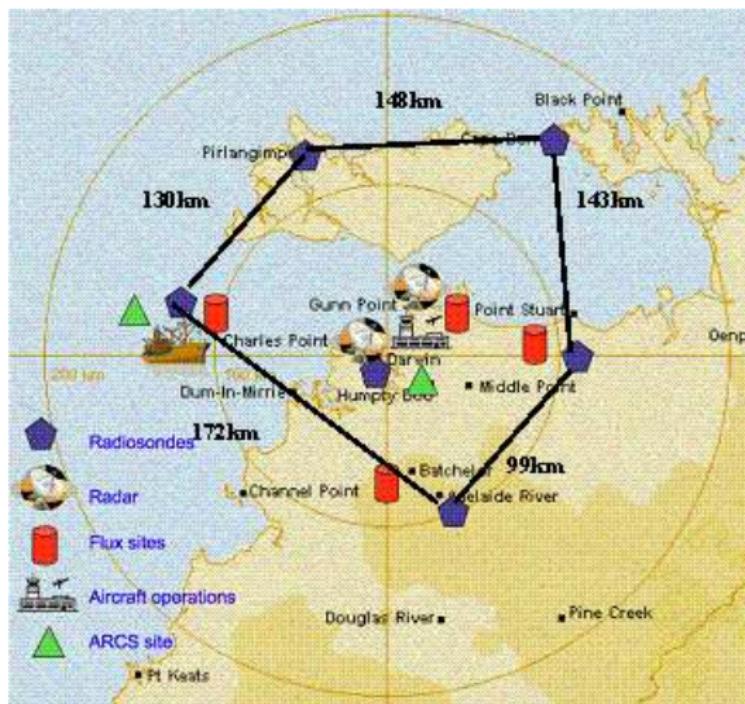


2004 Mixed-Phase Arctic Cloud Experiment (M-PACE)



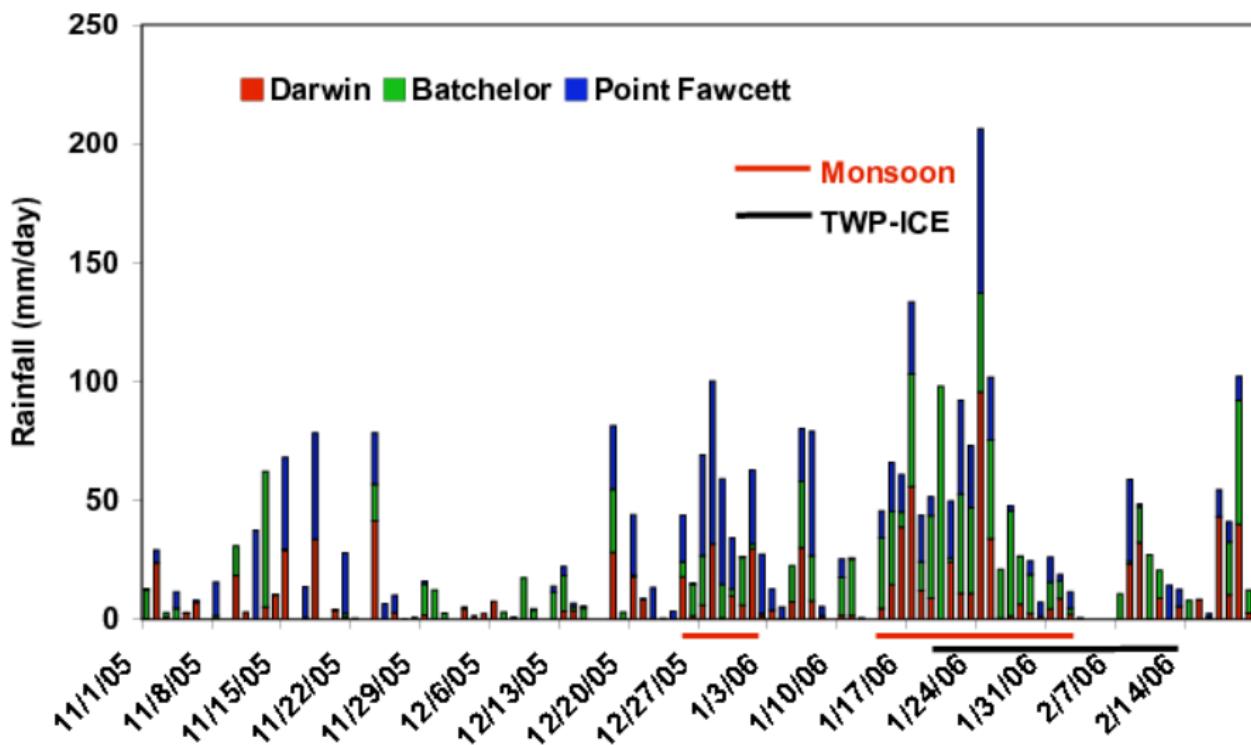
2006 Tropical Warm Pool—International Cloud Experiment (TWP-ICE)

Darwin, Australia



2006 Tropical Warm Pool—International Cloud Experiment (TWP-ICE)

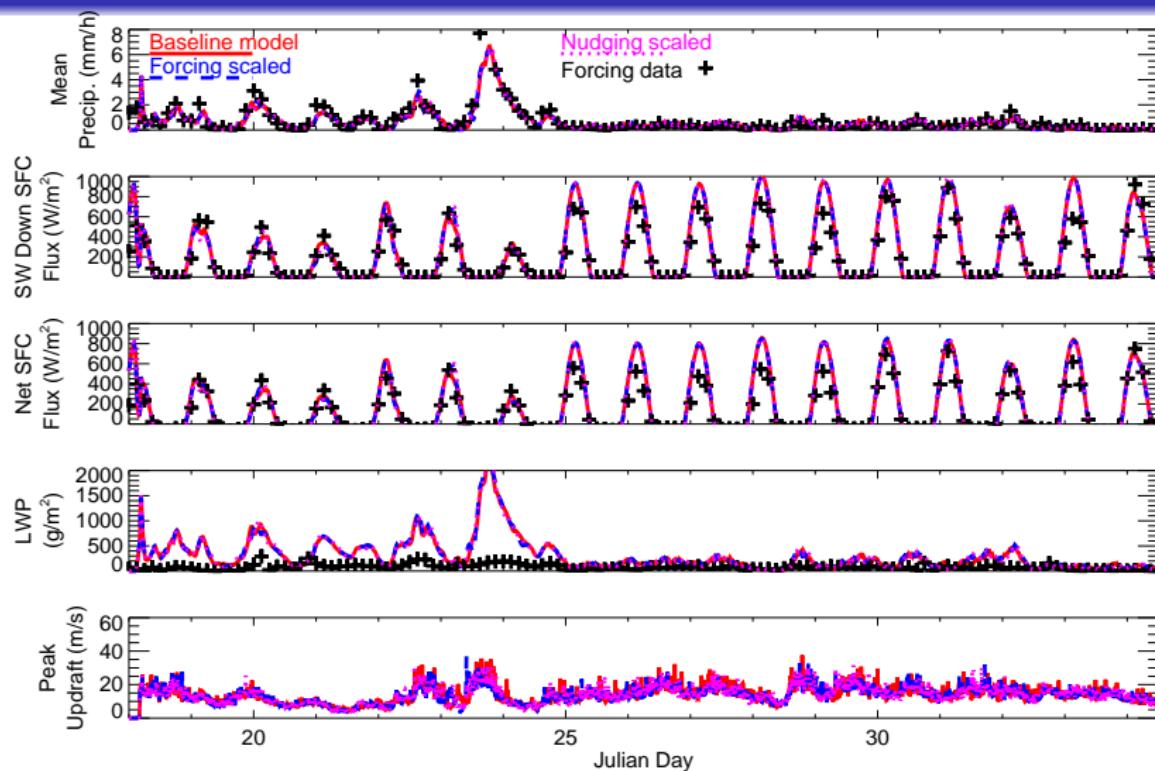
2005/2006 Wet Season



Source: Lori Chappel / Australian BOM

2006 Tropical Warm Pool—International Cloud Experiment (TWP-ICE)

Field Data vs Model Results



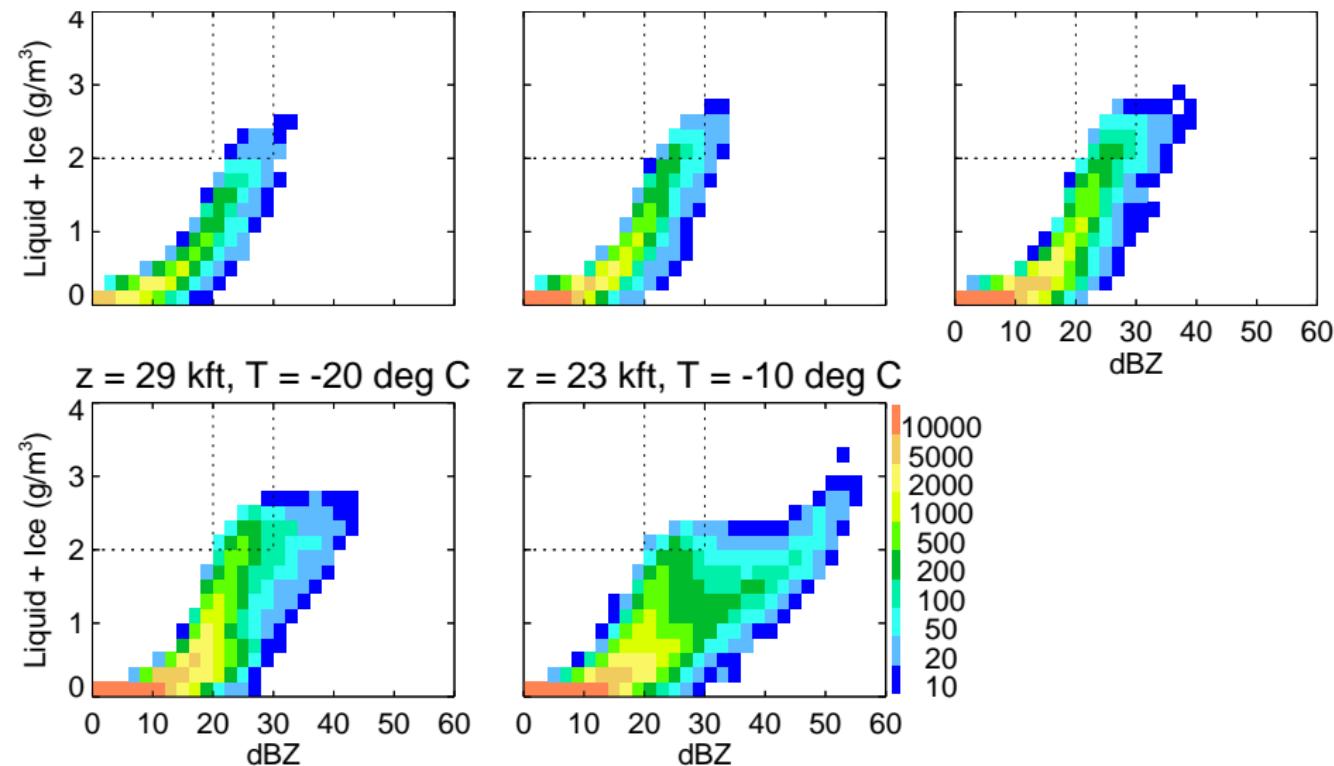
Source: Forcing data set courtesy Shaocheng Xie and Steve Klein

2006 Tropical Warm Pool—International Cloud Experiment (TWP-ICE)

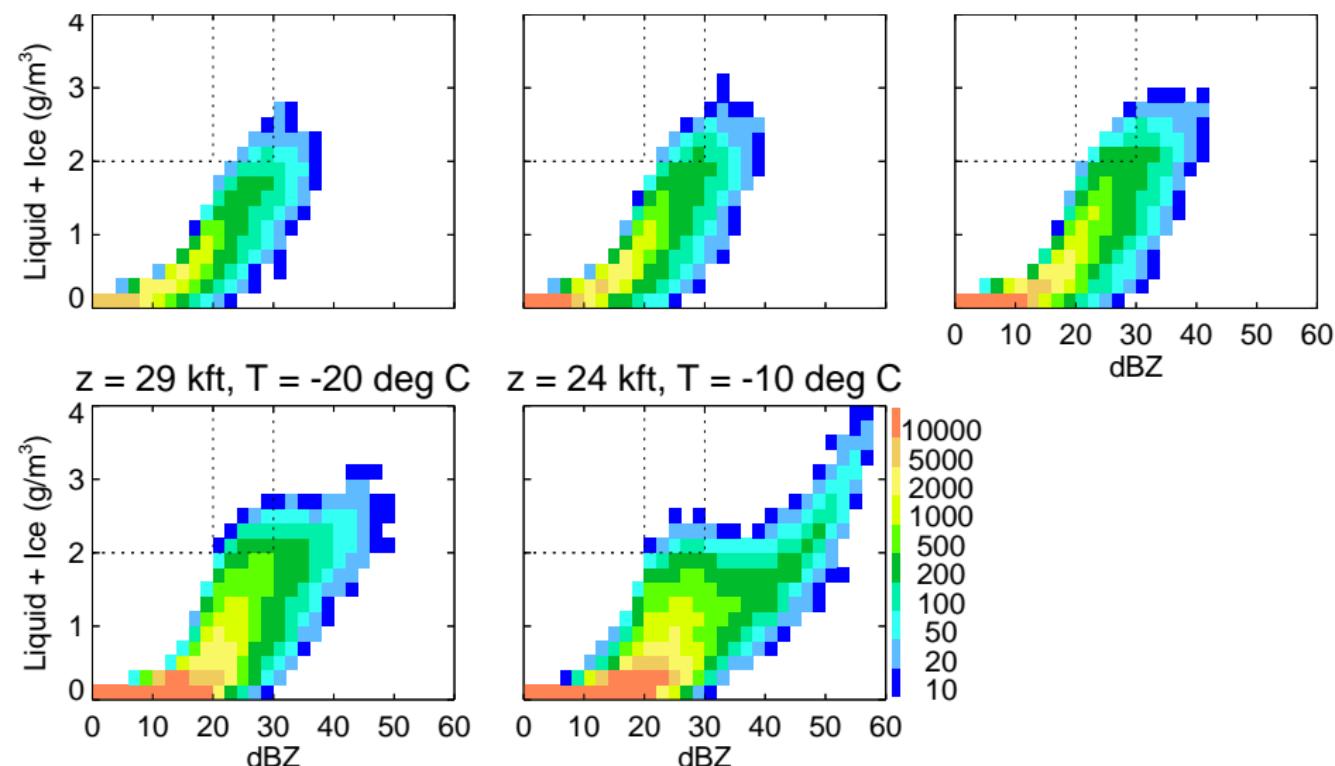
Simulated Cloud Mass (Liquid + Ice)

VIEW MOVIE

Simulated Cloud Mass and Radar Reflectivity (22 January)

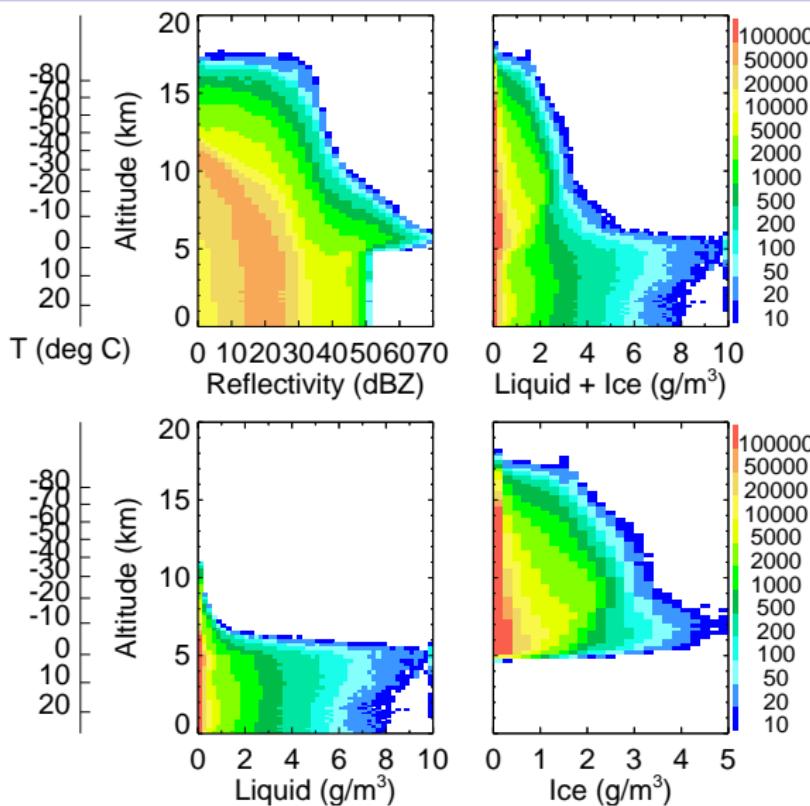


Simulated Cloud Mass and Radar Reflectivity (23 January)

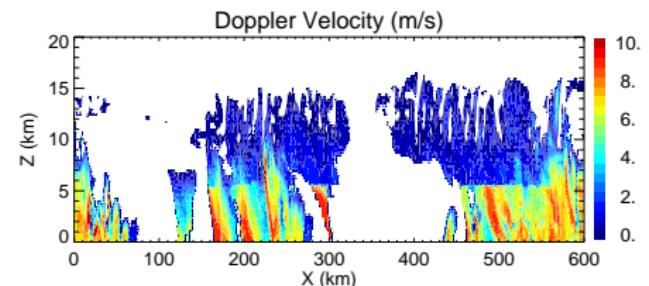
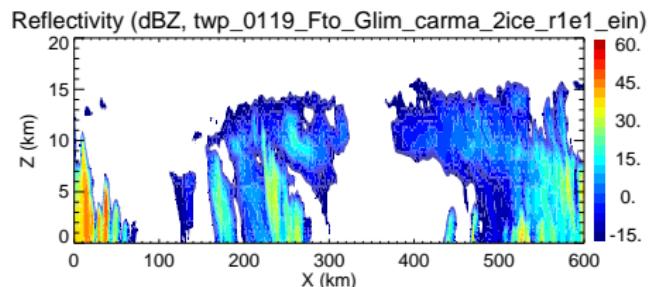
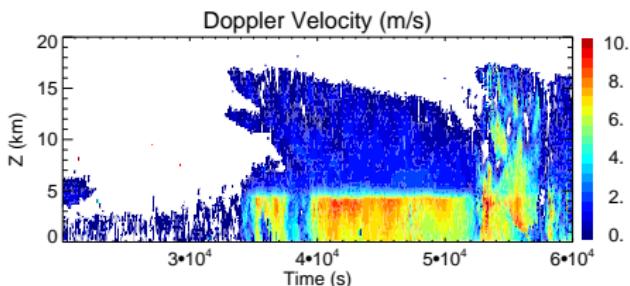
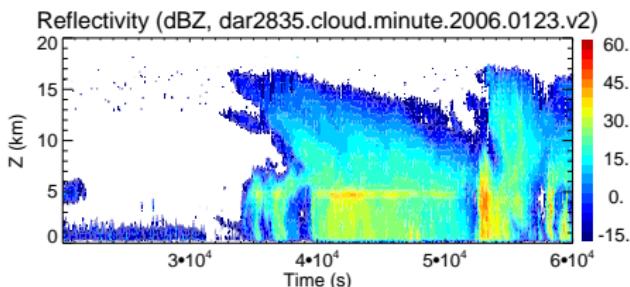


2006 Tropical Warm Pool—International Cloud Experiment (TWP-ICE)

Simulated Cloud Mass (23 January)



Constraining Results (S-Band Radar Data)



Source: Christopher Williams (NOAA), DOE ARM data archive

Using a Detailed 3-D Cloud-Resolving Model to Simulate Cloud Particle Size Distributions

Summary and Comments

- problem at hand
 - mixed-phase cloud ice formation mechanisms remain unclear
 - implications for understanding climate, weather, aviation safety
- modeling approach
 - complexity of microphysics, dynamics recommends modeling approach
 - this model type useful when size distributions are important
- two-fold interest in this campaign
 - share TWP-ICE results, help interpret them for this application
 - significant gains possible from probing convective storm cores
- related activities
 - study of ice formation in deep convective storms
 - joint DOE ARM / GCSS / SPARC modeling intercomparison
 - role in NASA Decadal Survey ACE mission design